Desired Signal = -68 dBm

Table A-9. Threshold U Statistics for 8 Receivers at D = -68 dBm on Channel 30

Undesired Channel	Best U (dBm)	Median U (dBm)	Mean U (dBm)	2nd Worst U (dBm)	Worst U (dBm)	Standard Deviation (dB)
N-16	> -1.1	-3.9	> -4.1	-5.9	-8.8	> 2.7
N-15	> -1.0	-3.9	> -4.0	-6.3	-8.3	> 2.7
N-14	> -0.8	-3.9	> -4.2	-6.4	-8.7	> 2.8
N-13	-1.0	-3.9	-4.4	-6.7	-9.2	2.8
N-12	-1.9	-5.3	-5.0	-6.7	-9.7	2.7
N-11	-2.1	-6.1	-5.9	-7.2	-11.2	2.8
N-10	-2.1	-4.5	-5.6	-8.4	-10.9	2.9
N-9	-3.1	-7.1	-7.1	-9.9	-11.9	3.1
N-8	-3.8	-10.0	-9.7	-13.0	-17.4	4.5
N-7	-3.8	-9.8	-10.8	-14.5	-19.6	5.1
N-6	-5.5	-15.1	-16.0	-19.7	-36.2	9.7
N-5	-5.4	-12.5	-13.7	-18.3	-23.5	5.7
N-4	-6.1	-20.6	-18.7	-22.2	-27.3	6.3
N-3	-8.2	-18.4	-17.9	-23.7	-26.2	6.3
N-2	-18.3	-27.2	-27.9	-36.0	-40.0	7.4
N-1	-28.0	-28.7	-28.9	-30.0	-30.1	0.8
N+1	-25.9	-28.3	-28.3	-29.6	-30.2	1.4
N+2	-19.7	-25.7	-26.9	-33.7	-38.2	6.9
N+3	-11.1	-13.3	-16.1	-19.7	-28.2	5.8
N+4	-8.1	-11.4	-13.1	-13.6	-27.0	5.9
N+5	-2.6	-9.6	-11.1	-14.5	-25.5	7.1
N+6	> -1.7	-4.9	> -6.4	-11.8	-15.2	> 4.6
N+7	-7.7	-14.8	-16.0	-23.0	-26.4	6.8
N+8	> -1.4	-3.0	> -3.4	-4.8	-7.1	> 2.0
N+9	> -1.4	-2.2	> -2.8	-4.5	-5.9	> 1.6
N+10	> -1.5	-3.0	> -3.0	-4.9	-5.2	> 1.4
N+11	> -1.8	>-2.2	> -2.8	-4.8	-4.9	> 1.3
N+12	> -2.0	>-2.3	> -3.0	-5.0	-5.1	> 1.3
N+13	> -2.1	>-2.5	> -3.0	-4.6	-4.8	> 1.1
N+14	> -2.7	-7.7	> -8.8	-15.1	-16.8	> 5.2
N+15	> -3.1	-12.9	> -12.0	-18.0	-19.3	> 5.7
N+16	> -3.5	>-3.8	> -3.9	-4.5	-4.6	> 0.4
N-5/N-10	-18.2	-25.7	-24.4	-26.3	-30.8	4.2
N-4/N-8	-21.7	-26.1	-25.6	-28.9	-29.8	3.1
N-3/N-6	-22.8	-26.3	-27.4	-32.0	-35.0	4.1
N-2/N-4	-16.7	-27.3	-28.7	-37.3	-38.5	6.9
N-1/N-2	-28.8	-32.3	-33.2	-38.1	-40.7	4.1
N+1/N+2	-28.3	-31.5	-31.9	-33.1	-39.0	3.4
N+2/N+4	-25.7	-30.0	-30.8	-37.1	-39.1	5.1
N+3/N+6	-17.0	-24.5	-24.0	-27.4	-34.1	5.8
N+4/N+8	-17.2	-21.2	-22.0	-25.8	-28.4	4.2
N+5/N+10	-15.6	-19.7	-20.1	-23.6	-25.5	3.2

Desired Signal = -53 dBm

Table A-10. Threshold U Statistics for 8 Receivers at D = -53 dBm on Channel 30

Undesired Channel	Best U (dBm)	Median U (dBm)	Mean U (dBm)	2nd Worst U (dBm)	Worst U (dBm)	Standard Deviation (dB)
N-16	> -0.8	-1.6	> -2.5	-3.7	-7.3	> 2.2
N-15	> -0.6	>-1.1	> -2.4	-4.0	-7.9	> 2.5
N-14	> -0.3	>-0.9	> -2.4	-4.2	-8.5	> 2.8
N-13	> -0.1	-1.1	> -2.5	-4.1	-8.8	> 2.9
N-12	> -0.1	-2.2	> -2.9	-4.4	-9.4	> 3.1
N-11	> -0.1	-2.0	> -3.2	-6.3	-10.1	> 3.5
N-10	> -0.1	-0.7	> -2.5	-4.8	-10.7	> 3.7
N-9	> -0.2	-0.8	> -2.8	-4.9	-11.6	> 3.9
N-8	> -0.4	-1.6	> -3.5	-5.8	-12.8	> 4.3
N-7	> -0.6	-2.5	> -4.1	-7.3	-14.2	> 4.7
N-6	> -0.9	-5.3	> -7.3	-16.2	-20.5	> 7.3
N-5	> -1.0	-1.4	> -4.6	-9.2	-18.3	> 6.2
N-4	> -1.1	-6.0	> -7.3	-13.0	-20.8	> 6.6
N-3	> -1.2	-3.8	> -4.9	-7.8	-11.1	> 3.3
N-2	-4.0	-11.5	-13.2	-21.2	-25.7	7.1
N-1	-13.1	-14.0	-14.6	-15.4	-18.6	1.8
N+1	-11.0	-13.6	-13.6	-14.7	-17.1	1.9
N+2	-6.2	-10.9	-12.4	-18.5	-22.7	6.3
N+3	> -2.1	-3.2	> -6.2	-4.9	-27.9	> 8.8
N+4	> -2.1	-2.9	> -6.4	-7.9	-23.9	> 7.4
N+5	> -1.8	-4.0	> -6.3	-8.5	-21.1	> 6.5
N+6	> -1.6	-2.2	> -4.1	-6.7	-13.2	> 4.1
N+7	-1.8	-14.3	-14.2	-20.4	-26.1	8.0
N+8	> -1.4	>-1.6	> -2.1	-3.4	-4.3	> 1.1
N+9	> -1.5	>-1.7	> -1.9	>-1.8	-3.8	> 0.8
N+10	> -1.6	>-1.8	> -1.9	>-1.9	-3.2	> 0.5
N+11	> -1.8	>-2.0	> -2.1	>-2.1	-2.7	> 0.3
N+12	> -1.8	>-2.2	> -2.2	>-2.3	-2.6	> 0.3
N+13	> -2.2	>-2.5	> -2.4	>-2.6	>-2.6	> 0.2
N+14	> -2.6	>-2.9	> -2.8	>-3.0	-3.1	> 0.2
N+15	> -3.0	>-3.3	> -3.5	>-3.4	-5.4	> 0.8
N+16	> -3.5	>-3.7	> -3.7	>-3.8	>-3.8	> 0.1
N-5/N-10	-14.1	-19.4	-18.7	-20.8	-22.4	2.8
N-4/N-8	-14.5	-18.5	-18.8	-20.5	-24.8	3.1
N-3/N-6	-9.4	-15.6	-16.6	-20.5	-27.6	5.8
N-2/N-4	-11.1	-14.8	-16.6	-24.4	-24.4	5.1
N-1/N-2	-14.0	-17.1	-18.6	-25.6	-26.7	4.9
N+1/N+2	-14.3	-17.6	-17.9	-19.7	-23.0	2.6
N+2/N+4	-14.1	-17.8	-19.6	-21.6	-32.2	5.7
N+3/N+6	-11.5	-18.8	-18.6	-23.1	-30.0	6.1
N+4/N+8	-11.8	-17.2	-17.0	-19.4	-24.5	4.1
N+5/N+10	-11.4	-14.8	-15.3	-18.7	-20.8	3.1

Desired Signal = -28 dBm

Table A-11. Threshold U Statistics for 8 Receivers at D = -28 dBm on Channel 30

Undesired Channel	Best U (dBm)	Median U (dBm)	Mean U (dBm)	2nd Worst U (dBm)	Worst U (dBm)	Standard Deviation (dB)
N-16	> -0.7	>-0.8	> -0.9	>-1.1	>-1.2	> 0.2
N-15	> -0.6	>-0.7	> -0.8	>-1.0	>-1.1	> 0.2
N-14	> -0.4	>-0.5	> -0.6	>-0.8	>-0.9	> 0.2
N-13	> -0.2	>-0.2	> -0.4	>-0.6	>-0.6	> 0.2
N-12	> -0.1	>-0.2	> -0.3	>-0.6	>-0.6	> 0.2
N-11	> -0.1	>-0.2	> -0.3	>-0.5	>-0.6	> 0.2
N-10	> -0.1	>-0.2	> -0.3	>-0.6	>-0.6	> 0.2
N-9	> -0.3	>-0.3	> -0.4	>-0.7	>-0.7	> 0.2
N-8	> -0.4	>-0.5	> -0.6	>-0.8	>-0.8	> 0.2
N-7	> -0.6	>-0.7	> -0.8	>-0.9	>-1.0	> 0.1
N-6	> -0.8	>-0.9	> -1.0	>-1.1	>-1.2	> 0.1
N-5	> -0.9	>-1.1	> -1.1	>-1.2	>-1.3	> 0.1
N-4	> -1.1	>-1.1	> -1.1	>-1.2	>-1.3	> 0.1
N-3	> -1.2	>-1.2	> -1.2	>-1.3	>-1.4	> 0.1
N-2	> -1.4	>-1.5	> -1.5	>-1.5	>-1.6	> 0.1
N-1	> -7.2	>-7.2	> -7.2	>-7.3	-7.3	> 0.0
N+1	> -7.7	>-7.8	> -7.8	>-7.8	-8.2	> 0.1
N+2	> -1.9	>-2.0	> -2.0	>-2.0	>-2.0	> 0.1
N+3	> -2.0	>-2.1	> -2.2	>-2.2	-2.7	> 0.2
N+4	> -2.0	>-2.2	> -2.2	>-2.2	>-2.2	> 0.1
N+5	> -1.8	>-2.0	> -2.0	>-2.0	>-2.1	> 0.1
N+6	> -1.5	>-1.7	> -1.7	>-1.8	>-1.8	> 0.1
N+7	> -1.5	>-1.6	> -2.7	-4.1	-8.0	> 2.3
N+8	> -1.4	>-1.6	> -1.6	>-1.7	>-1.7	> 0.1
N+9	> -1.4	>-1.7	> -1.7	>-1.8	>-1.9	> 0.2
N+10	> -1.5	>-1.8	> -1.8	>-1.9	>-2.0	> 0.2
N+11	> -1.7	>-2.1	> -2.0	>-2.1	>-2.2	> 0.2
N+12	> -1.9	>-2.2	> -2.2	>-2.3	>-2.4	> 0.2
N+13	> -2.1	>-2.5	> -2.4	>-2.6	>-2.6	> 0.2
N+14	> -2.5	>-2.8	> -2.8	>-2.9	>-3.0	> 0.2
N+15	> -2.9	>-3.3	> -3.2	>-3.4	>-3.4	> 0.2
N+16	> -3.5	>-3.7	> -3.7	>-3.9	>-3.9	> 0.1
N-5/N-10	NA	NA	NA	NA	NA	NA
N-4/N-8	NA	NA	NA	NA	NA	NA
N-3/N-6	NA	NA	NA	NA	NA	NA
N-2/N-4	NA	NA	NA	NA	NA	NA
N-1/N-2	> -7.1	>-7.2	> -7.7	-8.7	-9.9	> 1.0
N+1/N+2	> -7.7	>-7.8	> -8.3	-7.9	-11.7	> 1.4
N+2/N+4	NA	NA	NA	NA	NA	NA
N+3/N+6	NA	NA	NA	NA	NA	NA
N+4/N+8	NA	NA	NA	NA	NA	NA
N+5/N+10	NA	NA	NA	NA	NA	NA

APPENDIX B
THEORETICAL BASIS FOR OUT-OF-CHANNEL INTERFERENCE

When a DTV receiver operates in the presence of white Gaussian *co-channel* interference, the threshold of visibility (TOV) of picture degradation occurs when the desired signal power D exceeds the co-channel interference by about 15 dB.* This number may vary somewhat for noise having other statistical properties, and may be much lower if the noise is heavily concentrated at **a** band edge where filtering in the DTV provides additional rejection; nonetheless, one expects that, as signal power D varies, the undesired signal power at threshold will vary linearly with it—resulting a constant DIU ratio **as** D or U are varied. This relationship holds whenever the co-channel interference is high enough that the effect of internal noise in the receiver becomes insignificant.

For most *out-of-channel* interference mechanisms, the DTV receiver unintentionally converts a small portion of the out-of-channel power into co-channel power. If one knows the amount of conversion into co-channel interference, one can treat the problem as a co-channel interference problem, which is relatively well understood, as described above. In this formulation of the problem, measuring the desired signal power D at the TOV provides an indirect method of measuring the co-channel power created internal to the receiver, since we know that the co-channel power will be about 15 dB below the measured value of D.

The conversion process by the DTV from out-of-channel interference to co-channel interference may be linear or nonlinear. If it is linear, then the internally-created co-channel interference will vary linearly with the out-of-channel interference power U causing the value of the desired signal power D at threshold to vary linearly with U. The result will be that threshold DIU ratio will be constant **as** D or U is varied. If the conversion process is nonlinear, then the relationship between D and U will be nonlinear and the DIU ratio will vary with D and U.

We will assume that the *co-channel* interference power created by the DTV receiver in response to an *out-of-channel* undesired signal power U will be proportional to $D^L U^M$, where L and M are integer constants that define the ***order*** of the interferencemechanism. **For** most interference mechanisms, L will be zero, so only the U^M term exists. The following are among the interference mechanisms that can be modeled by this formulation.

- Linear interference: L=0, M=1. Creates co-channel interference proportional to U.
  - ◊ Example: mixer image. The mixer in a TV receiver converts the spectrum of the intended channel of the received signal to an intermediate frequency (IF) where it can be filtered more precisely to pass the desired channel while rejecting the undesired frequencies. Unfortunately, in single-conversion tuners a second a 6-MHz wide portion of the input spectrum centered 88 MHz above the desired channel is also converted to that same IF. Filtering prior to the mixer strongly diminishes—but doesn't fully extinguish—this unintended signal.
  - ◊ Example: leakage of the adjacent channel signal through the channel selection filter of the DTV would also constitute a linear interference mechanism.
- Second-order interference: L=0, M=2. Creates co-channel interference proportional to U^2.
  - 0 Example: "half-IF" taboo. The second harmonic of an undesired signal 22 MHz above the desired signal beats with the second harmonic of the receiver's local oscillator, creating a difference frequency that falls within the IF band of the receiver.
- Third-order interference: L=0, M=3. Creates co-channel interference proportional to U^3.

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* SHVEM Study results **on 28** receivers showed that D must exceed U by amounts ranging from 14.9 to 15.8 dB, with a median value of 15.3 dB.

- Example: third-order intermodulation (IM3) of a single, adjacent-channel undesired signal. IM3 creates spectral components that spill into each adjacent channel.
- Example: third-order intermodulation (IM3) of a pair of undesired channels placed at channels N+K and N+2K where N is the desired channel. In this case, the interference power created in channel N is proportional to $U_{N+K}{}^2U_{N+2K}$. The result is a process that is second-order in terms of U_{N+K} and linear in terms of U_{N+2K}; however, if the two undesired signals are set to equal powers and varied in amplitude together, the resulting interference is third order.

- Cross-modulation: L=1, M=2. Creates co-channel interference proportional to DU^2.
  - Cross-modulation is essentially a third-order effect, but the co-channel interference created is proportional to D and to U'. As a result, increasing the desired signal power does not improve the signal-to-interference ratio.

We define the following:
D = Power of desired signal on channel N at input to TV
U_{N+K} = Power of interferer on channel N+K at input to TV
U_{N+2K} = Power of interferer on channel N+2K at input to TV
where D, U_{N+K}, and U_{N+2K} refer to signal level combinations that place the TV at TOV

R = Required SNR of the TV receiver at TOV
D_{MIN} = D at TOV in absence of interference or external noise
N_R = Receiver noise referred to the input of the TV

Thus,
$R = D_{MIN}/N_R$
$N_R = D_{MIN}/R$

Consequently, N_R can be inferred from measurements of D_{MIN} and R

Let

P_{CC} = Total power of co-channel noise and interference affecting the demodulation of the DTV signal by the TV, referenced to the input. P_{CC} includes co-channel interference created by non-linear effects in the TV.

We will consider two cases. That of a single interferer with power U, where

$$P_{CC} = N_R + c\, U^M D^L$$

And that of third-order intermodulation (IM) between a pair of signals U_{N+K}, and U_{N+2K}

$$P_{CC} = N_R + c_{IM3}\, U_K{}' \, U_{2K}$$

The "c" terms are constants related to the nonlinear process in the receiver. The 1st term in each equation is receiver noise. The second is the interference term created by distortion in the TV tuner. The terms M and L define the order of the nonlinear interference process with respect to the undesired and desired signals, respectively.

We start with the case of a single interferer.

SINGLE INTERFERER

We have

$$P_{CC} = N_R + c\, U^M D^L$$

We will generally be interested in three cases:

- Linear interference mechanisms: $M = 1$; $L = 0$
- 2nd-order interference mechanisms: $M = 2$; $L = 0$
- 3rd-order interference mechanisms: $M = 3$; $L = 0$
- Cross-modulation: $M = 2$; $L = 1$

At TOV the desired signal must exceed P_{CC} by a factor equal to the required signal-to-noise ratio R. (We assume that the same value of R applies for both receiver noise and noise created by an undesired signal.) Thus

$D/P_{CC} = R$, or, equivalently,

$D = R\,P_{CC}$

Substituting, we have

$D = R\,(N_R + c\,U^M D^L)$

Substituting $N_R = D_{MIN}/R$, we have

$D = R\,c\,D^L U^M + D_{MIN}$

$U^M = (D - D_{MIN}) / (R\,c\,D^L)$

And, finally,

$U = [(D - D_{MIN}) / (R\,c\,D^L)]^{1/M}$

We will also find it useful to write this as

$U = D^{(1-L)/M}\,[(1 - D_{MIN}/D) / (R\,c)]^{1/M}$

High Signal Levels (D >> DMIN)

When $D \gg D_{MIN}$, the equation simplifies to

$U \approx [D^{1-L} / (R\,c)]^{1/M}$

$U \approx D^{(1-L)/M} / (R\,c)^{1/M}$

Similarly, D/U at threshold is given by

$D/U \approx D/[\,D^{(1-L)/M} / (R\,c)^{1/M}]$

$D/U \approx (R\,c)^{1/M}\,D^{(M-1+L)/M}$

Now we wish to view U and D in log-based units, such as decibels.

$\log(U) \approx \log[D^{(1-L)/M} / (R\,c)^{1/M}] = [(1 - L)/M] \log(D) - (1/M) \log(R\,c)$

$\log(D/U) \approx \log[(R\,c)^{1/M}\,D^{(M-1+L)/M}] = [(M - 1 + L)/M] \log(D) + (1/M) \log(R\,c)$

Thus a log-log plot of U versus D will be a straight line, with slope (1 – L) / M. Similarly, the slope of log-D versus log-U will be M / (1 – L), and the slope of log(D/U) versus log-D is given by [(M – 1 + L)/M].

Table A-1 summarizes this slope information for the interference mechanisms of interest.

*Table B-1. **Slopes** of Log-Log **Plots** of D, U, and D/U for Various Interference Mechanisms*

Interference Mechanism	Slope of Log (D) Versus Log (U) in dB/dB	Slope of Log (U) Versus Log (D) in dB/dB	Slope of Log (D/U) Versus Log (D) in dB/dB
Linear (M = 1, L = 0)	1	1	0
Second order (M = 2, L = 0)	2	0.5	0.5
Third order (including third-order intermodulation of a pair of equal-power interferers) (M = 3, L = 0)	3	0.333	0.667
Cross modulation (M = 2, L = 1)	Infinite	0	1

Low Signal Levels

The interference mechanisms described above are expected to result in linear relationships between log-U and log-D at threshold when the desired signal level is high enough that receiver noise is insignificant. Now we consider the case of smaller signal levels. Recall that

$$U = [(D - D_{MIN}) / (R_c D^L)]^{1/M}$$

Note that the presence of receiver noise (causing D_{MIN} to be non-zero and the log-U versus log-D relationship to deviate from a straight line) results in U changing by a factor of

$$[(D - D_{MIN}) / D]^{1/M}$$

Consider the case where D is X dB above D_{MIN}. Then U is Y dB above the value it would have had based on a straight-line log-log projection from the results at a high desired signal level.

$$X = 10 \log(D / D_{MIN})$$

$$Y = 10 \log\{[(D - D_{MIN}) / D]^{1/M}\}$$

$$Y = (1/M)\ 10 \log[1 - 10^{-X/10}] \text{ dB}$$

Table B-2 summarizes these results for three values of X.

Table B-2. Deviation in Threshold U from Straight-Line Projeciion as D Approaches D_{MIN}

Interference Mechanism	Deviation in Threshold U from Straight-Line Projection (dB)			
	D/D_{MIN}[1] = 16 dBm	D/D_{MIN} = 3 dB	D/D_{MIN} = 1 dB	D/D_{MIN} = 0 dB
Linear (M = 1)	-0.11	-3.02	-6.87	Infinite
Second order (M = 2)	-0.06	-1.51	-3.43	Infinite
Third order (including third-order intermodulation of a pair of equal-power interferers) (M = 3)	-0.04	-1.01	-2.29	Infinite
Cross modulation (M = 2, L = 1)	-0.06	-1.51	-3.43	Infinite

Note:
[1] *For* the nominal D_{MIN} value of *-84 dBm, D/D_{MIN} = 16 dB* **when** *D = -68 dBm*

Effect of AGC

The above relationships are expected to hold when automatic-gain-control (**AGC**) does not cause changes in gain between the TV antenna port and the point in the TV tuner at which the ***relevant nonlinearity*** occurs (*i.e.*, the location of the nonlinearity that causes the observed interference, assuming it is caused by a nonlinearity).

When either the desired signal power (D) or an undesired signal (U) rises sufficiently that **AGC** causes gain reductions *prior to the point oj a relevant nonlinearity*, the relationships change.

We define the following terms:

G = power gain from the antenna input tenninal of the TV to the point of a relevant nonlinearity;

G_{MAX} = the value of **G** when both **D** and U are low enough that **AGC** does not reduce the gain of any tuner stages prior to the nonlinearity;

In a television, **AGC** operation may be invoked based on increasing levels of either the desired signal D on channel N or of some filtered combination of desired and undesired signals.[*] In modeling **AGC**, we will assume that, if the **AGC** reduces gain of a tuner stage prior to the point of the relevant nonlinearity, it will do so in such a way **as** to achieve a constant power level with changes input signal level. Specifically, the power which is maintained constant by **AGC** action will be either the desired signal or the total power of some filtered combination of desired and undesired signals **(as** in the case of "broadband **AGC").** We will consider two bounding cases:

- **AGC** driven by **D. AGC** adjusts gain in such a way that the level of the *desired* signal at the point of the nonlinearity remains constant;
- **AGC** driven by U_{N+K}. **AGC** is controlled by a filtered combination of desired and undesired signals, but with undesired signal at the **AGC** sensing point being much larger than the desired signal, so that the **AGC** adjusts gain to, in effect, maintain a constant *undesired* signal power at the point of the relevant nonlinearity.

For each of these two cases, we define a signal level threshold above which the **AGC** reduces the gain of tuner stages prior to the point of the relevant nonlinearity:

$D_{AGCthresh}$ = the desired signal power at the TV input, above which **AGC** begins reducing **G;**

$U_{N-K,AGCthresh}$ = the undesired signal power on channel N+K, above which **AGC** begins reducing G.

[*] Bendov and Patel, 2005, **p.38-39.**

Thus, in the first case, we will assume that the AGC reduces gain by 1 dB for each 1-dB increase in D above $D_{AGCthresh}$. In the second case **we** assume that AGC reduces gain by 1 dB for each 1-dB increase in U beyond $U_{N-K,AGCthresh}$.

In the single-interferer case, recall that the total co-channel noise plus interference that seen by the receiver, referenced to input levels, is

$$P_{CC} = N_R + c\, U_{N+K}^M D^L$$

We note that this formula applies when gain prior to the relevant point of nonlinearity is at its maximum ($G = G_{MAX}$)—*i.e.*, the AGC hasn't caused any gain reductions. Thus, the formula is valid only when $D < D_{AGCthresh}$ and $U_K < U_{K\text{-}AGCthresh}$. If either AGC threshold **is** exceed, G is reduced and the fonnnla is no longer valid. We include the N+K subscript on U to emphasize that the AGC threshold will be different for different channel offsets because of filtering in the receiver.

It should be recognized that the terms U_{N+K}^M and D^L describe nonlinear behavior at some point in the TV tuner — perhaps at the mixer, or at the output of the IF amplifier. Thus, we could more correctly describe the nonlinearity in terms of signal levels at this point in the TV tuner. If we use bold italicized terms to represent desired signal power, undesired signal power, and receiver noise referred to the point of nonlinearity in the tuner, we can rewrite the equation as follows:

$$\boldsymbol{P_{CC}} = \boldsymbol{N_R} + \boldsymbol{c_I}\, \boldsymbol{U_{N+K}}^M \boldsymbol{D}^L \quad \text{when } G = G_{MAS}$$

where
$\boldsymbol{P_{CC}} = G\, P_{CC}$
$\boldsymbol{N_R} = G\, N_R$
c_I = a new constant describing the nonlinearity in terms of levels at the point of nonlinearity, instead of at referenced to the input
$\boldsymbol{U_{N+K}} = G\, U_{N+K}$
$\boldsymbol{D} = G\, D$

Performing substitutions, we have

$$G\, P_{CC} = G\, N_R + c_I\, (G\, U_{N+K})^M (G\, D)^L$$

$$G\, P_{CC} = G\, N_R + c_I\, G^{M+L}\, U_{N+K}^M D^L$$

$$P_{CC} = N_R + c_I\, G^{M+L-1}\, U_{N+K}^M D^L$$

$$P_{CC} = N_R + c_I\, G_{MAX}^{M+L-1}\, (G/G_{MAX})^{M+L-1}\, U_{N+K}^M D^L$$

When $G = G_{MAX}$, this formula must be equivalent to the previous version:

$$P_{CC} = N_R + c\, U_{N+K}^M D^L \quad \text{when } G = G_{MAX}$$

Thus, it is clear that the relationship between the nonlinearity constant defined referenced to the input and that defined referenced to the point of the nonlinearity is

$$c = c_I\, G_{MAX}^{M+L-1}$$

Consequently, we will rewrite the new formula as follows:

$$P_{CC} = N_R + c\,(G/G_{MAX})^{M+L-1}\,U_{N+K}{}^M\,D^L$$

At threshold, $P_{CC} = D/R$; also $R\,N_R = D_{MIN}$. So we have

$$D = R\,[N_R + c\,(G/G_{MAX})^{M+L-1}\,U_{N+K}{}^M\,D^L$$

$$D = D_{MIN} + R\,c\,(G/G_{MAX})^{M+L-1}\,U_{N+K}{}^M\,D^L$$

<u>AGC Driven By D</u>
We first consider the case in which the ***<u>desired</u>*** signal reaches a sufficient level to cause AGC gain reductions before the point of the relevant nonlinearity. We assume that

$$G/G_{MAX} \quad = 1, \qquad \text{when } D \le D_{AGCthresh}, \text{ and}$$
$$= D_{AGCthresh}/D, \qquad \text{when } D > D_{AGCthresh}$$

Thus, for the case of $D > D_{AGCthresh}$, we have

$$D = D_{MIN} + R\,c\,(D_{AGCthresh}/D)^{M+L-1}\,U^M\,D^L]$$

$$D - D_{MIN} = R\,c\,D_{AGCthresh}{}^{M+L-1}\,U^M\,D^{-M+1}]$$

$$U^M = (D - D_{MIN})\,D^{M-1}\,/(R\,c\,D_{AGCthresh}{}^{M+L-1})$$

$$U = [(D - D_{MIN})\,D^{M-1}\,/(R\,c\,D_{AGCthresh}{}^{M+L-1})]^{1/M}$$

$$U = [(D - D_{MIN})\,D^{M}\,/(R\,c\,D\,D_{AGCthresh}{}^{M+L-1})]^{1/M}$$

$$U = D\,[(D - D_{MIN})\,/(R\,c\,D\,D_{AGCthresh}{}^{MIL-1})]^{1/M}$$

$$U = D\,[(1 - D_{MIN}/D)\,/(R\,c\,D_{AGCthresh}{}^{M+L-1})]^{1/M}$$

We recall and rearrange the original formula that applies when there are no **AGC** gain reductions,

$$U = [(D - D_{MIN})\,/\,(R\,c\,D^L)]^{1/M}$$

$$U = D^{(1-L)/M}\,[(1 - D_{MIN}/D)\,/\,(R\,c)]^{1/M}$$

We now combine this with the case of no AGC gain changes.

With **AGC** operation driven by desired signal level,

$U =$ $\quad D\,[(I - D_{MIN}/D)\,/(R\,c\,D_{AGCthresh}{}^{M+L-1})]^{1/M}$, when $D > D_{AGCthresh}$ (*i.e.*, AGC operating)

$\quad D^{(1-L)/M}\,[(1 - D_{MIN}/D]\,/\,(R\,c)]^{1/M}$, when $D \le D_{AGCthresh}$ (*i.e.*, no **AGC** operation)

Consider the case when $D >> D_{MIN}$. The formula becomes,

$U \approx$ $\quad D\,[1\,/\,(R\,c\,D_{AGCthresh}{}^{MIL-1})]^{1/M}$, when $D > D_{AGCthresh}$ (*i.e.*, AGC operating)

$D^{(1-L)/M} / (R\,c)^{1/M}$, when $D \leq D_{AGCthresh}$ (*i.e.*, no AGC operation)

Notice that the first formula (for use when the AGC is operating) is linear in D. *I.e.*, the threshold undesired signal is directly proportional to the desired signal level. This means that, at signal **levels** $D >> D_{MIN}$, the interference behaves as if it is linear, even though the underlying mechanism is nonlinear. ***For D >> D_{MIN}, once D exceeds the AGC thresholdfor gain adjustmentsprior to the point of the relevant nonlinearity, D/U ratio remains constant with further increases in D. Beyond this AGC threshold, the interference behaves as if it derivesfrom a linear mechanism, even though the actual interference mechanism may be nonlinear.***

The above statement applies to $D >> D_{MIN}$. We now examine further the case of small signal levels.

$U = D\,[(1 - D_{MIN}/D)/(R\,c\,D_{AGCthresh}{}^{MIL-1})]^{1/M}$, when $D > D_{AGCthresh}$ (*i.e.*, AGC operating)

Or

$U = D\,(1 - D_{MIN}/D)^{1/M} / (R\,c\,D_{AGCthresh}{}^{MIL-1})^{1/M}$, when $D > D_{AGCthresh}$ (*i.e.*, AGC operating)

We can see that the presence of receiver noise (causing non-zero D_{MIN}) causes the undesired signal threshold U to change by a factor of

$(1 - D_{MIN}/D)^{1/M}$, when $D > D_{AGCthresh}$ (*i.e.*, AGC operating)

The effect of receiver noise on threshold U is the same result that was obtained when D was below the AGC threshold.

<u>**AGC** Driven by U</u>

Now consider the case in which the ***<u>undesired</u>*** signal reaches a sufficient level to cause AGC gain reductions before the point of the relevant nonlinearity. We assume that

$$G/G_{MAX} = 1, \quad \text{when } U_{N+K} \leq U_{N+K\text{-}AGCthresh}, \text{ and}$$
$$= U_{N+K,AGCthresh}/U_{N+K}, \quad \text{when } U_{N+K} > U_{N+K\text{-}AGCthresh}$$

Thus, for the case $U_{N+K} > U_{N+K,AGCthresh}$, we have

$$D = D_{MIN} + R\,c\,(G/G_{MAX})^{M+L-1}\,U_{N+K}{}^{M}\,D^{l}$$

Substituting for G/G_{MAX},

$$D = D_{MIN} + R\,c\,(U_{N+K,AGCthresh}/U_{N+K})^{M+L-1}\,U_{N+K}{}^{M}\,D^{l}$$

Rearranging,

$$D - D_{MIN} = R\,c\,U_{N+K,AGCthresh}{}^{M+L-1}\,U_{N+K}{}^{1-L}\,D^{l}$$

$$U_{N+K}{}^{1-L} = (D - D_{MIN}) / \{R\,c\,U_{N+K,AGCthresh}{}^{M+L-1}\,D^{L}]$$

There is no solution when L = I, the cross-modulation case. For other cases, where L = 0,

$U_{N+K} = (D - D_{MIN}) / [R\, c\, U_{N+K,AGCthresh}^{M-1}]$

We now combine this with the case of no AGC gain changes

With AGC operation driven by the undesired signal level,	
$U_{N+K} = (D - D_{MIN}) / (R\, c\, U_{N+K,AGCthresh}^{M-1})$,	when $U_{N+K} > U_{N+K,AGCthresh}$, (*i.e.*, AGC operating), L = 0;
$D^{(1-L)/M} [(1 - D_{MIN}/D] / (R\, c)]^{1/M}$,	when $U_{N+K} \leq U_{N+K,AGCthresh}$ (*i.e.*, no AGC operation)

By requiring that L = 0, we are excluding the case of cross-modulation from the solution when the AGC is operating on undesired signal level. Recall that, for large desired signal levels well above D_{MIN}, the solution to the no-AGC cross-modulation case is a fixed value of U, independent of D, because the co-channel interference power created by the TV tuner is directly proportional to D; a 1-dB increase in D causes a 1-dB increase in co-channel interference power, so changing D doesn't get you closer to, or take you further from, the TOV. If we consider the case with AGC driven by undesired signal, our hypothesis is that the **AGC** acts to keep the power of the ***undesired*** signal at a fixed level at the point of the nonlinearity by driving down the gain as the undesired signal at the input increases. The net effect, then, of a 1-dB increase in undesired signal at the input will be that the undesired signal power at the point of nonlinearity remains constant, but the power of the desired signal at that point decreases. As we described above, such a change does not move the operating point either closer to, or further from, the TOV. Rather, whether the TV operates error free will depend only on whether the AGC threshold is above or below the TOV threshold for U that results from the cross-modulation process.

Note that, in the formula that applies when AGC is operating, we find that **U is** directly proportional to D if D >> D_{MIN}. Thus, the AGC operation causes the interference to act as if it were linear, even if the underlying mechanism is nonlinear.

At low signal levels, the effect of receiver noise is identical to that for a linear process

Except in the case of cross-modulation, AGC operation that is driven by <u>undesired</u> signal level causes the interference to behave as if it were created by a linear process. This conclusion applies both to the slope of log-U versus log-D at high signal levels, and to the deviation from that straight-line log-log carve at low signal levels.

IM3 WITH PAIRED SIGNALS

When a pair of undesired signals placed on channels N+K and N+2K, nonlinearities in the receiver can create third-order intermodulation products in the desired channel N.

If the undesired signals are set to equal amplitudes **(U** $= U_{N+K} = U_{N+2K}$), then the results are identical to the third-order interference case described above. More generally, we substitute $U_{N+K}^2\, U_{N+2K}$ for U^3 in those formulas.

$$D = R\,(N_R + c\, U_{N+K}^2\, U_{N+2K})$$

$$D = D_{MIN} + R\, c\, U_{N+K}^2\, U_{N+2K}$$

If the two undesired signals have equal power ($U = U_{N+K} = U_{N+2K}$) and $D >> D_{MIN}$ so that receiver noise is insignificant, the equation simplifies to

$$D = R\,c\,U^3$$

Or,

$D/R = c\,U^3$ = IM3 power referred to the input of the TV receiver.

Rhodes and Sgrignoli point out that IM3 is often computed in terms of the third-order intercept power (IP3) for an amplifier or receiver..[*] In decibel units, this is written as,

$$IM3|_{dB} = 3\,U|_{dB} - 2\,IP3|_{dB}$$

In linear power units, the equation can be rewritten as

$$IM3 = U^3 / IP3^2$$

Using this in our equation,[†]

$$D/R = c\,U^3 = IM3 = U^3 / IP3^2$$

In this form we see that our constant c is equal to $1/IP3^2$ and our original equation (when receiver noise is insignificant) becomes

$$D = (R / IP3^2)\,U_{N+K}^{\;2}\,U_{N+2K}$$

Given measurements at threshold for D and U, along with knowledge of the required SNR of the DTV receiver (R), we could compute IP3 as follows (when the two undesired signals are equal):

$$IP3 = (R\,U^3 / D)^{1/2}$$

Rather than do this, we will group the IP3 and R terms.

$$IP3 / R^{1/2} = (U^3 / D)^{1/2}$$

$$\boxed{IP3 / R^{1/2} = (U^3 / D)^{1/2}}$$

or, in decibel units,

$$\boxed{(IP3 / R^{1/2})|_{dB} = 1.5\,U|_{dB} - 0.5\,D|_{dB}}$$

Once we know $IP3 / R^{1/2}$, we can use it in our original, more general equation.

$$D = D_{MIN} + R\,c\,U_{N+K}^{\;2}\,U_{N+2K}$$

[*] For example, see Rhodes and Sgrignoli, 2005, p. 464.

[†] We note that **IP3** is typically defined in this way for narrowband signals. Here we use a definition that, while similar to the narrowband case, is not the same because: (1) we are using to model **IM3** with broadband signals rather than sinusoids, and **(2)** we are interested only in the IM3 power than falls **in** TV channel N although the IM3 **signal** also extends into channels N-1 and N+1.

$D = D_{MIN} + U_{N+K}^2 U_{N+2K} / (IP3 / R^{1/2})^2$

If we know one of the two undesired signals, we can determine the threshold value of the other from:

$U_{N+K}^2 U_{N+2K} = (IP3 / R^{1/2})^2 (D - D_{MIN})$

$$\boxed{\begin{aligned} U_{N+K} &= (IP3 / R^{1/2}) (D - D_{MIN})^{1/2} / U_{N+2K}^{1/2} \\ U_{N+2K} &= (IP3 / R^{1/2})^2 (D - D_{MIN}) / U_{N+K}^2 \end{aligned}}$$

If $D >> D_{MIN}$, then the equations can be converted to dB **as** follows:

$$\boxed{\begin{aligned} U_{N+K}|_{dB} &= (IP3 / R^{1/2})|_{dB} + (D|_{dB} - U_{N+2K}|_{dB}) / 2 \\ U_{N+2K}|_{dB} &= 2\ (IP3 / R^{1/2})|_{dB} + D|_{dB} - 2\ U_{N+K}|_{dB} \end{aligned}}$$

AGC With Paired-Signal IM3

We consider the case of AGC operating in such **a** way **as** to maintain one of the two undesired signals at a constant power level at the point of the nonlinearity that causes the observed IP3.

We begin with AGC operation based on the power of the first of the two undesired signals. We assume that

$$G/G_{MAX} = \begin{cases} 1, & \text{when } U_{N+K} \le U_{N+K\text{-}AGCthresh}, \text{ and} \\ U_{N+K,AGCthresh}/U_{N+K}, & \text{when } U_{N+K} > U_{N+K\text{-}AGCthresh} \end{cases}$$

Thus, for the case $U_{N+K} > U_{N+K,AGCthresh}$, we have

$D = D_{MIN} + (G/G_{MAX})^2 U_{N+K}^2 U_{N+2K} / (IP3 / R^{1/2})^2$

Substituting for G/G_{MAX},

$D = D_{MIN} + (U_{N+K,AGCthresh}/U_{N+K})^2 U_{N+K}^2 U_{N+2K} / (IP3 / R^{1/2})^2$

Rearranging,

$D - D_{MIN} = (U_{N+K,AGCthresh})^2 U_{N+2K} / (IP3 / R^{1/2})^2$

Thus when the AGC is driven by the power of U_{N+K}, the desired signalpower at threshold is linearly related to the power of the second undesired signal U_{N+2K} and independent of the power of first undesired signalpower U_{N+K}. At a constant desired signalpower, the threshold of U_{N+2K} is constant—independent of U_{N+K}.

Now we consider the case of **AGC** operation based on the power of the second undesired signal. We assume that

G/G_{MAX} $= 1,$ when $U_{N+2K} \le U_{N+2K\text{-}AGCthresh}$, and
$= U_{N+2K,AGCthresh}/U_{N+2K}$, when $U_{N+2K} > U_{N+2K\text{-}AGCthresh}$

Thus, for the case $U_{N+2K} > U_{N+2K,AGCthresh}$, we have

$$D = D_{MIN} + (G/G_{MAX})^2\, U_{N+K}^{2}\, U_{N+2K} / (IP3 / R^{1/2})^2$$

Substituting for G/G_{MAX},

$$D = D_{MIN} + (U_{N+2K,AGCthresh}/U_{N+2K})^2\, U_{N+K}^{2}\, U_{N+2K} / (IP3 / R^{1/2})^2$$

Rearranging,

$$D - D_{MIN} = (U_{N+2K,AGCthresh})^2\, (U_{N+K}^{2} / U_{N+2K}) / (IP3 / R^{1/2})^2$$

Recall that, for values below the AGC threshold, each 1-dB increase in the power of U_{N+2K} causes a 0.5 dB decrease in the undesired signal power that can be tolerated on U_{N+K} for a given desired signal power. When the AGC is driven by the power of U_{N+2K}, this trend reverses above the AGC threshold. At constant a desired signal power, each 1 dB increase in U_{N+2K} above the AGC threshold causes a 0.5-dB increase in the undesired signal power that can be tolerated on channel N+K.

SUMMARY

Single Undesired Signals

Interference creating by linear or non-linear effects within a TV receiver acting on incoming signals has been modeled as a conversion of the incoming signals into co-channel interference with a power proportional to $D^L U^M$, where D and U represent the desired and undesired signal powers, respectively, at the input to the TV receiver. The model has been developed for the following types of interference mechanisms:

- Linear (M = 1; L = 0)
- Second-order (M = *2;* L = 0)
- Third-order (M = 3; L = 0)
- Cross-modulation (M = **2;** L = 1)

The model includes the effects of receiver noise at low signal levels

The basic model applies to the case in which no AGC-induced gain changes occur between the input of the receiver and the point in the tuner at which the interference mechanism is created (usually a nonlinearity). The model is then extended to include the changed behavior that occurs when AGC acts to reduce gain prior to the point at which the interference is created. The AGC model assumes that, for signal levels above a certain threshold, the gain will be adjusted in such a way as to maintain a constant signal level at the point at which the interference is created. In practice, that constant signal level assumption may apply to the desired signal power D or to a filtered sum of desired and undesired signal powers. The AGC model considers two bounding cases of such operation:

- AGC driven by ***desired*** signal power. AGC adjusts gain in such a way that the level of the desired signal at the point of the nonlinearity remains constant;
- AGC driven by undesired signal power. Here we assumed that the AGC is controlled by a filtered combination of desired and undesired signals, hut with undesired signal at the AGC-sensing point being much larger than the desired signal, ***so*** that the AGC adjusts gain to, in effect, maintain a constant ***undesired*** signal power at the point of the relevant nonlinearity.

Relevant formulas for undesired signal power at TOV are:

$U_{N+K} = D^{(1-L)/M}\,[(1 - D_{MIN}/D) / (R\,c)]^{1/M}$, when $D \le D_{AGCthresh}$ and $U_{N+K} \le U_{N+K,AGCthresh}$ (*i.e.*, no **AGC** operation)

$U_{N+K} = D\,[(1 - D_{MIN}/D) / (R\,c\,D_{AGCthresh}{}^{M(L-1)})]^{1/M}$, when $D > D_{AGCthresh}$ (*i.e.*, **AGC** operating to keep desired signal constant at the point in the receiver at which the interference is created)

$U_{N+K} = (D - D_{MIN}) / (R\,c\,U_{N+K,AGCthresh}{}^{M-1})$, when $U_{N+K} > U_{N+K,AGCthresh}$ (*i.e.*, **AGC** operating to keep the undesired signal power constant at the point in the receiver at which the interference is created) and $L = 0$ (*i.e.*, the formula does not apply to cross-modulation).

where,

D = Power of desired signal on channel N at input to TV
U = Power of the undesired, out-of-channel signal at channel N+K at input to TV
(D and U refer to signal level combinations that place the TV at TOV)
R = Required SNR by TV at TOV
D_{MIN} = Desired signal at TOV in absence of interference or external noise
c = a constant describing the interference mechanism

When operating well above the minimum desired signal level that a TV can demodulate (in the absence of interference), the interference model predicts that a log-log plot of undesired signal power (U) versus desired signal power (D) or a log-log plot of DIU ratio versus desired signal power (D) (*i.e.*, plots in units of decibels) will be linear, with a slope determined by the interference mechanism and the **AGC** operation. The slopes are summarized in Table **B-4.**

Table B-3. Slopes of Log-Log Plots of D, U, and D/U for Various Interference Mechanisms

Interference Mechanism	Slope of Log (D) Versus Log (U) in dB/dB	Slope of Log (U) Versus Log (D) in dB/dB	Slope of Log (D/U) Versus Log (D) in dB/dB	Characterization
Linear (M = 1)	1	1	0	Constant D/U
Second order (M = 2)	2	0.5	0.5	
Third order (including third-order intermodulation of a pair of equal-power interferers) (M = 3)	3	0.333	0.667	
Cross modulation (M = 2, L = 1)	Infinite	0	1	Constant U
AGC-Stabilized Nonlinear	1	1	0	Constant D/U

As desired signal power approaches D_{MIN}, the threshold of the receiver in the absence of interference, the undesired signal deviates from the log-log straight line by amounts shown in Table **B-4.**

Table *B-4.* Deviation in Threshold *U from Straight-Line* Projection ***as*** *D* approaches D_{MIN}

Interference Mechanism	Deviation in Threshold U from Straight-Line Projection (dB)			
	D/D_{MIN}[1] = 16 dBm	**D/D_{MIN} = 3 dB**	**D/D_{MIN} = 1 dB**	**D/D_{MIN} = 0 dB**
Linear (M = 1)	-0.1	**-3.0**	-6.9	Infinite
Second order (M = 2)		-1.5	**-3.4**	Infinite
Third order (including third-order intermodulation of a pair of equal-power interferers) (M = 3)		-1.0	**-2.3**	Infinite
Cross modulation (M = 2, L = 1)		-1.5	**-3.4**	Infinite
AGC-Stabilized Nonlinear w/U driving AGC[2]	-0.1	**-3.0**	-6.9	Infinite

Note:
[1] For the nominal D_{MIN} value of *-84 dBm, D/D_{MIN}* = 16*dB* when *D* = -68 *dBm*
[2] With desired signal driving ***AGC,*** deviation from straight-line projection matches that *of* the original nonlinear process, except in the case of cross-modulation, which is not addressed.

Third-Order Intermodulation With Paired Signals at N+K and N+2K

Third-order intermodulation between paired signals at N+K and N+2K was modeled as follows

D =Power of desired signal on channel N at input to TV
U_{N+K} =Power of interferer on channel **N+K** at input to TV
U_{N+2K} = Power of interferer on channel N+2K at input to TV

where D, U_{N+K}, and U_{N+2K} refer to signal level combinations that place the TV at TOV

R = Required SNR of TV at TOV
D_{MIN} = Desired signal at TOV in absence of interference or external noise
IP3 = Third-order intercept point of the receiver under the current **AGC** conditions

We define the interference performance in terms of a parameter that combines IP3 with the required SNR of the DTV receiver (nominally 15.3 dB, or 33.9). The parameter is computed from measurements of threshold values of undesired and desired signals when the two undesired signals have equal power ($U = U_{N+K} = U_{N+2K}$).

$$IP3 / R^{1/2} = (U^3 / D)^{1/2}$$

or, in decibel units,

$$(IP3 / R^{1/2})|_{dB} = 1.5\, U|_{dB} - 0.5\, D|_{dB}$$

Once we know $IP3 / R^{1/2}$, we can use it in one of the following equations to determine the threshold for one undesired signal in terms of the other undesired signal power.

$$U_{N+K} = (IP3 / R^{1/2})(D - D_{MIN})^{1/2} / U_{N+2K}^{1/2}$$

$$U_{N+2K} = (IP3 / R^{1/2})^2 (D - D_{MIN}) / U_{N+K}^2$$

If $D >> D_{MIN}$, then the equations can be converted to dB as follows:

$$U_{N+K}|_{dB} = (IP3 / R^{1/2})|_{dB} + (D|_{dB} - U_{N+2K}|_{dB}) / 2$$

$$U_{N+2K}|_{dB} = 2\,(IP3 / R^{1/2})|_{dB} + D|_{dB} - 2\,U_{N+K}|_{dB}$$

AGC With Paired-Signal IM3

When gain is constant, each 1-dB increase in the power of U_{N+K} causes a 2-dB decrease in the undesired signal power that can be tolerated on U_{N+2K} at a constant desired signal power. Conversely, each 1-dB increase in the power of U_{N+2K} causes a 0.5-dB decrease in the undesired signal power that can be tolerated on U_{N+K}.

If the **AGC** acts to keep the power of U_{N+K} constant at the point of the nonlinearity that creates the observed IM3, the threshold of U_{N+2K} becomes a linear function of desired signal power and is independent of U_{N+K}.

If the **AGC** acts to keep the power of U_{N+2K} constant at the point of the nonlinearity that creates the observed IM3, the fixed-gain trend reverses. **At** constant a desired signal power, each 1 dB increase in U_{N+2K} above the **AGC** threshold causes a **0.5-dB** *increase* in the undesired signal power that can be tolerated on channel N+K.

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